UNIT # 7
PROPERTIES OF MATTER

Q1. Describe briefly about matter?

Ans: Matter exists in three states, solid, liquid and gas. There are many properties associated with matter. For example, matter has weight and occupies space.

For example, solids have shape of their own while liquids and gases do not. Liquids on the other hand have definite volume while gases do not have. Various materials differ in their hardness, density, solubility, flow, elasticity, conductivity and many other qualities. Kinetic molecular model helps in understanding the properties of matter in a simplified way.

Q2. How kinetic molecular model of matter is helpful in differentiating various states of matter?

Ans: See Q # 7.2 from Exercise.

USEFUL INFORMATION

Density of various substances	
Substance	**Density in kgm^{-1}**
Air	1.3
Foam	89
Petrol	800
Cooking Oil	920
Ice	920
Water	1000
Glass	2500
Aluminum	2700
Iron	7900
Copper	8900
Lead	11200
Mercury	13600
Gold	19300
Platinum	21500

USEFUL INFORMATION

1 metre cube (1 m^3)	= 1000 litre
1 litre	= 10^{-3} m^3
1 cm^3	= 10^{-6} m^3
1000 kgm^{-3}	= 1 gcm^{-3}

Q3. Is an iron object heavier than that of wood?

OR

Why is 1 cm cubed of wood lighter than 1 cm cubed of iron?

Ans: Because centimeters cubed is a unit of volume, not weight. The two might take up the same amount of space, but iron is much more dense and as such weighs more. $\text{Density} = \frac{\text{mass of a substance}}{\text{volume of that substance}}$ *OR* $D = \frac{m}{V}$

Q4. What is meant by density? What is its SI unit?

Ans: See Q # 7.4 from Exercise.

Q5. Calculate the density of 5 litre of water?

Solution:

The mass of 5 litre of water is 5 kg.

Since

$$1 \text{ litre} = 10^{-3}\ m^3$$

$$5 \text{ litre} = 5 \times 10^{-3}\ m^3$$

$$\text{Density} = \frac{\text{mass of a substance}}{\text{volume of that substance}} \quad OR \quad D = \frac{m}{V}$$

$$\text{Density of water} = \frac{5\ kg}{5 \times 10^{-3}\ m^3}$$

$$= 1000\ kg\ m^{-3}$$

The density of water is $1000\ kg\ m^{-3}$.

Q6. Write down the density equations?

Ans: Density equations:

(i) $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$

(ii) $\text{Mass} = \text{Density} \times \text{Volume}$

(iii) $\text{Volume} = \frac{\text{Mass}}{\text{Density}}$

DO YOU KNOW?

Earth's atmosphere extends upward about a few hundred kilometres with continuously decreasing density. Nearly half of its mass is between sea level and 10 km. Up to 30 km from sea level contains about 99% of the mass of the atmosphere. The air becomes thinner and thinner as we go up.

Q7. Define the term pressure.

Ans: See Q # 7.6 from Exercise.

Q8. Show that atmosphere exerts pressure.

Ans: See Q # 7.7 from Exercise.

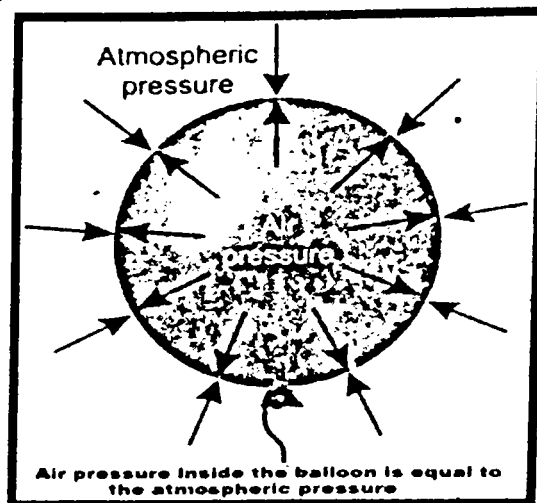
Q9. How soap bubbles are produced. Why the soap bubbles so formed have spherical shapes?

Ans: Formation of soap bubbles:

A soap bubble is a very thin sheet of water sandwiched between two layers of soap molecules. The film of soapy water surrounds a bubble of air. Soap molecules have one end that repels water, and one that attracts it, and these molecules move to the inner and outer surfaces, thrusting their water-repelling ends out into the air, and their "heads" inwards. Without such molecules on the surface, the bubble would spontaneously break apart into tiny water droplets.

Spherical shape of soap bubbles:

Surface tension causes the bubble to be spherical, which is the shape that gives the minimum surface energy - the lowest ratio of surface area to volume.

Soap bubbles expand till the pressure of air in them is equal to the atmospheric pressure.

Q10. Write about the factors affecting pressure?

Ans: Factors Affecting Pressure $P = \frac{F}{A}$

i. the size of the force – the greater the force the greater the pressure.
ii. the area of contact – the smaller the area the greater the pressure.

Q11. Write any three examples of pressure?

Ans: Examples of Pressure

(i) Skis have a large area to hold up the weight of the skier on the snow.
(ii) Flat bottomed shoes are comfortable to wear due to reduced pressure acting on our feet.
(iii) A sharp knife can cut easily because the very high pressure under the cutting surface is more than the object can withstand.
(iv) In some situations a highly concentrated force is useful so a small area of contact is desirable e.g. scissors, knife edge, nail point, cheese wire, spikes on golf shoes, sharp edge of a spade.
(v) In other situations low pressure is better and so a large area of contact is part of the design e.g. wide tyres, school bag straps, suitcase handle, broad feet of elephant and camel.

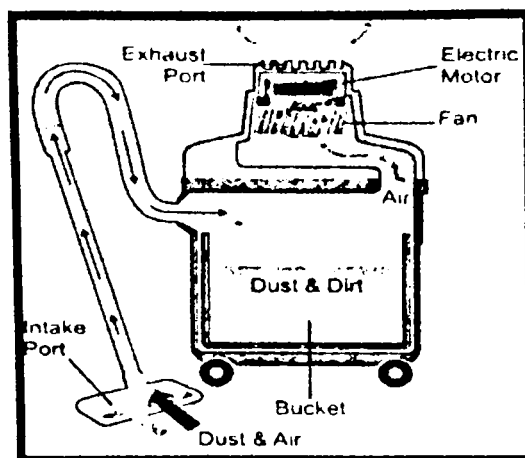
Q12. What is a barometer?

OR

Write the procedure for measuring atmospheric pressure with the help of barometer?

Ans: See Q # 7.9 from Exercise.

DO YOU KNOW?

The fan in a vacuum cleaner lowers air pressure in its bucket. The atmospheric air rushes into it carrying dust and dirt with it through its intake port. The dust and dirt particles are blocked by the filter while air escapes out.

Q13. Why does the atmospheric pressure vary with height?

Ans: Variation in atmospheric pressure:

The atmospheric pressure decreases as we go up. The atmospheric pressure on mountains is lower than at sea level. At a height of about 30 km, the atmospheric pressure becomes only 7 mm of mercury which is approximately 1000 Pa. It would become zero at an altitude where there is no air. Thus, we can determine the altitude of a place by knowing the atmospheric pressure at that place.

Atmospheric pressure may also indicate a change in the weather. On a hot day, air above the Earth becomes hot and expands. This causes a fall of atmospheric pressure in that region. On the other hand, during cold chilly nights, air above the Earth cools down. This causes an increase in atmospheric pressure.

Q14. What does it mean when the atmospheric pressure at a place fall suddenly?

Ans: See Q # 7.13 from Exercise.

Q15. What changes are expected in weather if the barometer reading shows a sudden increase?

Ans: See Q # 7.14 from Exercise.

Q16. Why does atmospheric pressure change with altitude?

Ans: See Q # 7.12 from Exercise.

DO YOU KNOW?

When air is sucked through straw with its other end dipped in a liquid, the air pressure in the straw decreases. This causes the atmospheric pressure to push the liquid up the straw.

Q17. State relation for pressure beneath a liquid surface to depth and to density?

OR

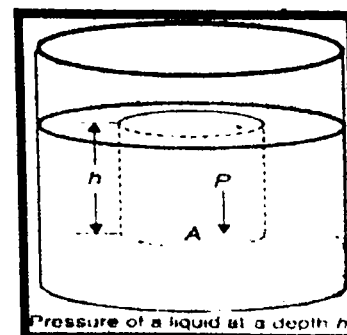
Prove that ($P = \rho gh$).

Ans: Pressure in Liquids:

Consider a surface of area A in a liquid at a depth h. The length of the cylinder of liquid over this surface will be h.

The force acting on this surface will be the weight w of the liquid above this surface. If ρ is the density of the

h P A

Pressure of a liquid at a depth h

liquid and m is mass of liquid above the surface, then

Mass of the liquid cylinder $= m =$ volume $\times$ density

$= (A \times h) \times \rho$

Force acting on area A $\quad F = w = m g$

$= A h \rho g$

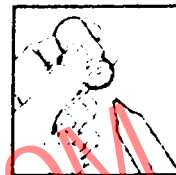
as Pressure $\quad P = \frac{F}{A}$

$= \frac{A h \rho g}{A}$

Liquid pressure at depth h $= P = \rho g h$ .... (i)

Equation (i) gives the pressure at a depth h in a liquid of density ρ. It shows that its pressure in a liquid increases with depth. ($P \propto h$)

DO YOU KNOW?

The piston of the syringe is pulled out. This lowers the pressure in the cylinder. The liquid from the bottle enters into the piston through the needle.

Q18. State Pascal's law.

Ans: See Q # 7.15 from Exercise.

Q19. Explain the working of hydraulic press.

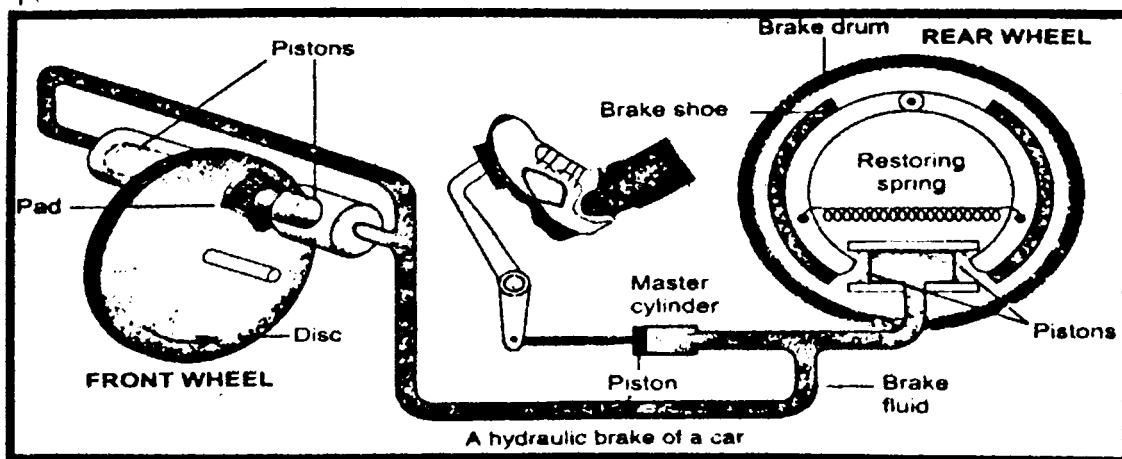
OR

Small force applied on the smaller piston, results into a large force on the larger piston. Why?

Ans: See Q # 7.16 from Exercise

Q20. Explain the breaking system in vehicles?

Ans: Braking system in vehicles:

The braking systems of cars, buses, etc. also work on Pascal's law. The hydraulic brakes allow equal pressure to be transmitted throughout the liquid. When brake pedal is pushed, it exerts a force on the master cylinder, which increases the liquid pressure in it. The liquid pressure is transmitted equally through the liquid in the metal pipes to all the pistons of other cylinders. Due to the increase in liquid pressure, the pistons in the cylinders move outward pressing the brake pads with the brake drums. The force of friction between the brake pads and the brake drums stops the wheels.

A hydraulic brake of a car

Q21. State Archimedes principle.

Ans: See Q # 7.18 from Exercise.

DO YOU KNOW?

Hydrometer:

Hydrometer is a glass tube with a scale marked on its stem and heavy weight in the bottom. It is partially immersed in a fluid, the density of which is to be measured. One type of hydrometer is used to measure the concentration of acid in a battery. It is called acid meter.

Q22. Determine the density of an object using Archimedes principle?

Ans: Density of an object:

Archimedes principle is also helpful to determine the density of an object. The ratio in the weights of a body with an equal volume of liquid is the same as in their densities.

Let Density of the object = D

Density of the liquid = ρ

Weight of the object = w_1

Weight of equal volume of liquid = w = $w_1 - w_2$

Here w_2 is the weight of the solid in liquid. According to Archimedes principle, w_2 is less than its actual weight w_1 by an amount w.

Since
$$\frac{D}{\rho} = \frac{w_1}{w}$$

$$D = \frac{w_1}{w} \times \rho$$

or
$$D = \frac{w_1}{w_1 - w_2} \times \rho \qquad \ldots\ldots \text{(i)}$$

Thus, finding the weight of the solid in air w_1 and its weight in water w_2, we can calculate the density of the solid by using equation (i) as illustrated in the following example.

Figure: (a) weighing solid in air (b) weighing solid in water and measuring water displaced by the solid.

Q23. What is upthrust? Explain the principle of floatation.

Ans: See Q # 7.19 from Exercise.

Q24. Explain how a wooden block, ships and boats moves up the water surface.

Ans: A wooden block floats on water. It is because the weight of an equal volume of water is greater than the weight of the block. According to the principle of floatation, a body floats if it displaces water equal to the weight of the body when it is partially or completely immersed in water.

Ships and boats are designed on the same principle of floatation. They carry passengers and goods over water. It would sink in water if its weight including the weight of its passengers and goods becomes greater than the upthrust of water.

Q25. Explain how a submarine moves up the water surface and down into water.

Ans: See Q # 7.20 from Exercise.

Q26. What is meant by deforming force?

Ans: Deforming force:

We know that the length of a rubber band increases on stretching it. Similarly, the pointer of a spring balance is lowered when a body is suspended from it. It is because the length of the spring inside the balance increases depending upon the weight of the suspended body.

The applied force that changes shape, length or volume of a substance is called deforming force. In most of the cases, the body returns to its original size and shape as soon as the deforming force is removed.

Figure (a) A spring is stretched by a force (b) A rod is twisted by the torque produced by a couple (c) A strip is bent by a force.

Q27. What is meant by elasticity?

Ans: Elasticity:

The property of a body to restore its original size and shape as the deforming force ceases to act is called elasticity.

Due to elasticity we can determine the strength of a material and the deformation produce under the action of a force.

Q28. Differentiate between stress and strain?

Ans: Stress:

The force acting on unit area at the surface of a body is called stress.

Thus $\text{Stress} = \dfrac{\text{Force}}{\text{Area}}$

Unit: In SI, the unit of stress is newton per square metre (Nm^{-2}).

Strain:

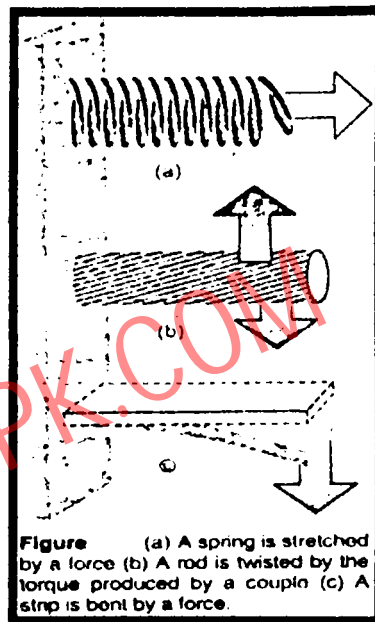
A comparison of such a change caused by the stress with the original length, volume or shape is called as strain.

If stress produces a change in the length of an object then the strain is called tensile strain.

$$\text{Tensile strain} = \frac{\text{change in length}}{\text{original length}}$$

Strain has no units as it is simply a ratio between two similar quantities.

Q29. What is Hooke's law? What is meant by elastic limit?

Ans: See Q # 7.22 from Exercise.

Q30. What do you know about Young's modulus? How would you determine young's modulus of an object?

Ans: Young's modulus:

The ratio of stress to tensile strain is called Young's modulus.

Determination of young's modulus:

Consider a long bar of length L_o and cross-sectional area A. Let an external force F equal to the weight w stretches it such that the stretched length becomes L According to Hooke's law, the ratio of this stress to tensile strain is constant within the elastic limit of the body.

Young's modulus $Y = \frac{\text{Stress}}{\text{Tensile strain}}$

Let ΔL be the change in length of the rod, then

$$\Delta L = L - L_o$$

Since Stress $= \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$

and Tensile strain $= \frac{L-L_o}{L_o} = \frac{\Delta L}{L_o}$

As $Y = \frac{\text{Stress}}{\text{Tensile strain}}$

$$= \frac{F}{A} \times \frac{L_o}{\Delta L}$$

$$Y = \frac{F L_o}{A \Delta L}$$

Unit: SI unit of Young's modulus is newton per square metre (Nm^{-2}).

SUMMARY

1. **Kinetic molecular model:** Kinetic molecular model explains the three states of matter assuming that
   - matter is made up of particles called molecules.
   - the molecules remain in continuous motion.
   - molecules attract each other.
2. **Plasma:** At very high temperature, the collision between atoms and molecules tears off their electrons. Atoms become positive ions. This ionic state of matter is called plasma-the fourth state of matter.
3. **Density:** Density is the ratio of mass to volume of a substance. Density of water is 1000 kgm^{-3}.
4. **Pressure:** Pressure is the normal force acting per unit area. Its SI unit is Nm^{-2} or pascal (Pa).
5. Atmospheric pressure acts in all directions.
6. **Barometer:** The instruments that measure atmospheric pressure are called barometers.
7. The atmospheric pressure decreases as we go up. Thus, knowing the atmospheric pressure of a place, we can determine its altitude.
8. The changes in atmospheric pressure at a certain place indicate the expected changes in the weather conditions of that place.

9. Liquids also exert pressure given by: $P = \rho g h$
10. **Pascal's law:** Liquids transmit pressure equally in all directions. This is called Pascal's law.
11. **Archimedes principle:** When a body is immersed wholly or partially in a liquid, it loses its weight equal to the weight of the liquid displaced. This is known as Archimedes principle.
12. For an object to float, its weight must be equal or less than the upthrust of the liquid acting on it.
13. **Elasticity:** The property of matter by virtue of which matter resists any force which tries to change its length, shape or volume is called elasticity.
14. **Stress:** Stress is the deforming force acting per unit area.
15. **Tensile strain:** The ratio of change of length to the original length is called tensile strain.
16. **Young's modulus:** The ratio between stress and tensile strain is called Young's modulus.

QUESTIONS

7.1 Encircle the correct answer from the given choices:

i. In which of the following state molecules do not leave their position?

A. solid B. liquid
C. gas D. plasma

ii. Which of the substances is the lightest one?

A. copper B. mercury
C. aluminum D. lead

iii. SI unit of pressure is pascal, which is equal to:

A. 10^4 Nm^{-2} B. 1 Nm^{-2}
C. 10^2 Nm^{-2} D. 10^3 Nm^{-2}

iv. What should be t approximate length of a glass tube to construct a water barometer?

A. 0.5 m B. 1 m
C. 2.5 m D. 11 m

v. According to Archimedes upthrust is equal to:

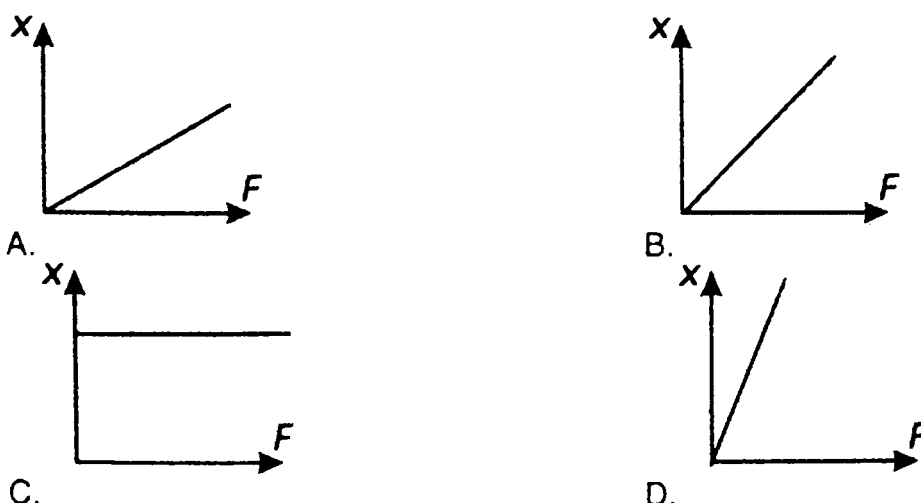
A. weight of displaced liquid B. volume of displaced liquid
C. mass of displaced liquid D. none of these

vi. The density of a substance can be found with the help of:

A. Pascal's law B. Hooke's law
C. Archimedes principle D. Principle of floatation

vii. According to Hooke's law

A. stress × strain = constant B. stress / strain = constant
C. strain / stress = constant D. stress = strain

The following force-extension graphs of a spring are drawn on the same scale. Answer the questions given below from (viii) to (x).

viii. Which graph does not obey Hooke's law?

A. B. C. D.

ix. Which graph gives the smallest value of spring constant?

A. B. C. D.

x. Which graph gives the largest value of spring constant?

A. B. C. D.

Answers

i. A	ii. C	iii. B	iv. B	v. A
vi. C	vii. B	viii. C	ix. D	x. A

7.2 How kinetic molecular model of matter is helpful in differentiating various states of matter?

Ans: Kinetic Molecular Model of Matter:

(i) Matter is made up of particles called molecules.

(ii) The molecules remain in continuous motion.

(iii) Molecules attract each other.

Characteristics of Kinetic Molecular Model of Matter:

Kinetic molecular model is used to explain the three states of matter - solid, liquid and gas.

a. Solids:

(i) Solids such as a stone, metal spoon, pencil, etc. have fixed shapes and volume.

(ii) Molecules of solids are held close together by strong forces of attraction.

(iii) Molecules of solids vibrate about their mean positions but do not move from place to place.

b. Liquids:

(i) The distances between the molecules of a liquid are more than in solids. Thus, attractive forces between them are weaker.

(ii) Like solids, molecules of a liquid also vibrate about their mean position but are not rigidly held with each other.

(iii) Due to the weaker attractive forces, they can slide over one another. Thus, the liquids can flow.

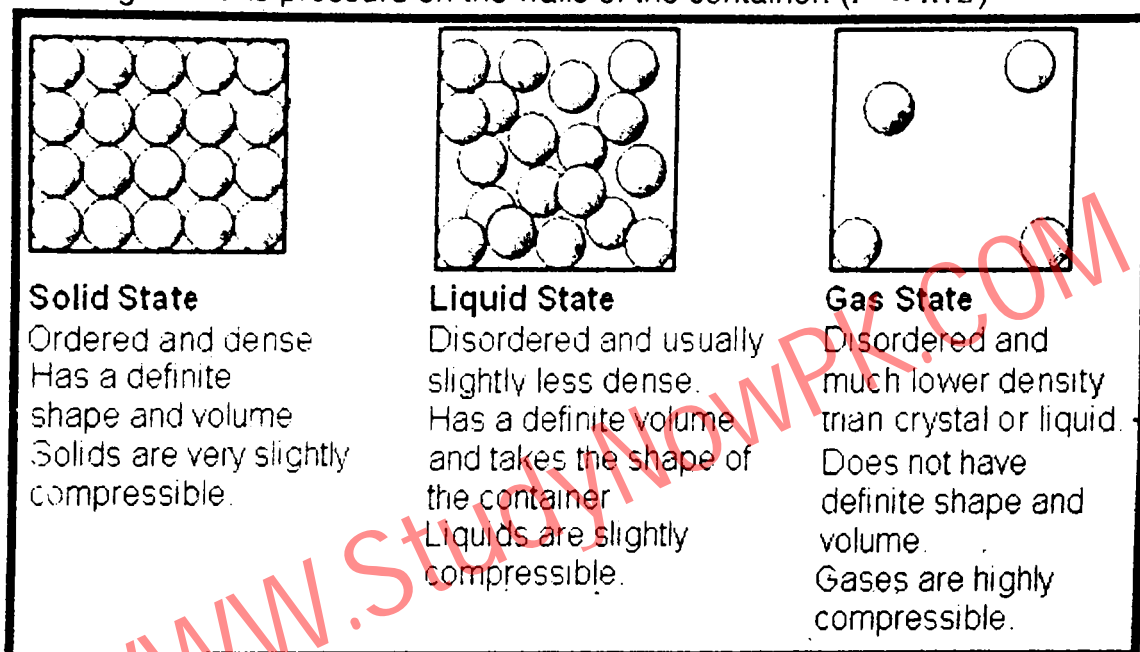
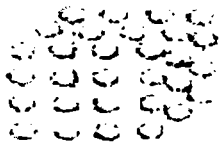
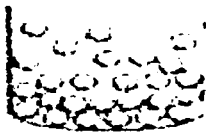
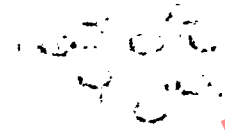
(iv) The volume of a certain amount of liquid remains the same but because it can flow hence, it attains the shape of a container to which it is put.

c. Gases:

(i) Gases such as air have no fixed shape or volume. They can be filled in any container of any shape.

(ii) Their molecules have random motion and move with very high velocities. In gases, molecules are much farther apart than solids or liquids. Thus, gases are much lighter than solids and liquids.

(iii) They can be squeezed into smaller volumes.

(iv) The molecules of a gas are constantly striking the walls of a container. Thus, a gas exerts pressure on the walls of the container. ($P \propto K.E$)

d. Plasma - The fourth state of matter:

(i) Production/Formation of plasma:

The kinetic energy of gas molecules goes on increasing if a gas is heated continuously. This causes the gas molecules to move faster and faster. The collisions between atoms and molecules of the gas become so strong that they tear off the atoms. Atoms lose their electrons and become positive ions. This ionic state of matter is called **plasma**. Plasma is also formed in gas discharge tubes when electric current passes through these tubes.

(ii) Plasma is called the **fourth state of matter** in which a gas occurs in its ionic state. Positive ions and electrons get separated in the presence of electric or magnetic fields.

(iii) Plasma also exists in neon and fluorescent tubes when they glow.

(iv) Most of the matter that fills the universe is in plasma state.

(v) In stars such as our Sun, gases exist in their ionic state.

(vi) Plasma is highly conducting state of matter. It allows electric current to pass through it.

Solid	Liquid	Gas	Plasma
Ice H_2O	Water H_2O	Steam H_2O	Ionized Gas $H_2 \rightarrow H^+ + H^+ + 2e^-$
Cold $T<0°C$	Warm $0<T<100°C$	Hot $T>100°C$	Hotter $T>100,000°C$ (>10 electron Volts)
Molecules Fixed in Lattice	Molecules Free to Move	Molecules Free to Move, Large Spacing	Ions and Electrons Move Independently, Large Spacing

7.3 Does there exist a fourth state of matter? What is that?

Ans: Yes, fourth state of matter is called plasma.

Plasma:

At very high temperature, the collision between atoms and molecules tears off their electrons. Atoms become positive ions. This ionic state of matter is called plasma-the fourth state of matter.

7.4 What is meant by density? What is its SI unit?

Ans: Density:

Density of a substance is defined as its mass per unit volume.

$$\text{Density} = \frac{\text{mass of a substance}}{\text{volume of that substance}} \quad OR \quad D = \frac{m}{V}$$

Unit of Density:

SI unit of density is kilogramme per cubic metre (kgm^{-3}).

7.5 Can we use a hydrometer to measure the density of milk?

Ans: Lactometer is used to measure the density of milk. Whereas hydrometer is used to measure the concentration of acid in a battery. It is called acid meter.

7.6 Define the term pressure.

Ans: Pressure:

The force acting normally per unit area on the surface of a body is called pressure.

Thus Pressure $P = \frac{Force}{Area}$

or $$P = \frac{F}{A}$$

Pressure is a scalar quantity.

Unit of pressure:

In SI units, the unit of pressure is Nm^{-2} also called pascal (Pa). Thus

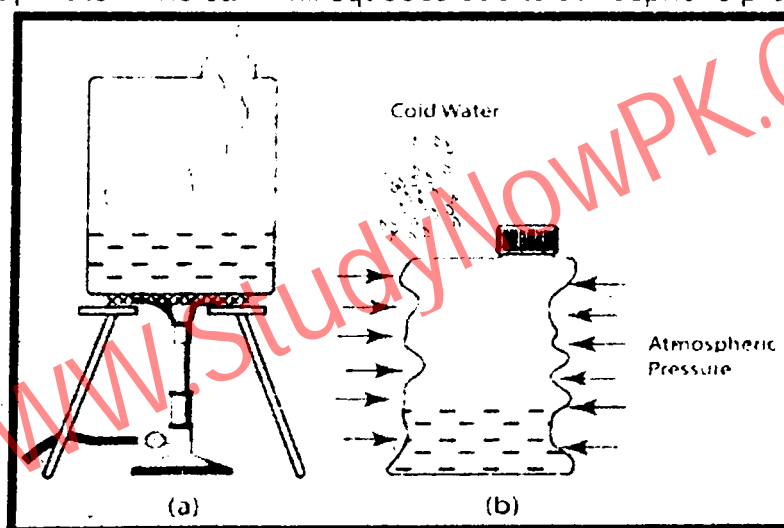
$$1\ Nm^{-2} = 1\ Pa$$

7.7 Show that atmosphere exerts pressure.

Ans: Atmospheric Pressure:

The Earth is surrounded by a cover of air called atmosphere. It extends to a few hundred kilometres above sea level. Just as certain sea creatures live at the bottom of ocean, we live at the bottom of a huge ocean of air. Air is a mixture of gases. The density of air in the atmosphere is not uniform, it decreases continuously as we go up. Atmospheric pressure acts in all directions.

Experiment:

Take an empty tin can with a lid. Open its cap and put some water in it. Place it over flame. Wait till water begins to boil and the steam expels the air out of the can. Remove it from the flame. Close the can firmly by its cap. Now place the can under tap water. The can -will squeeze due to atmospheric pressure.

When the can is cooled by tap water, the steam in it condenses. As the steam changes into water, it leaves an empty space behind it. This lowers the pressure inside the can as compared to the atmospheric pressure outside the can. This will cause the can to collapse from all directions. This experiment shows that atmosphere exerts pressure in all directions.

The fact can also be demonstrated by collapsing of an empty plastic bottle when air is sucked out of it.

7.8 It is easy to remove air from a balloon but it is very difficult to remove air from a glass bottle. Why?

Ans: This is because the air inside the balloon is at a fairly high pressure than the atmosphere pressure air outside the balloon. On the other hand air pressure inside the glass bottle is already equal to the atmospheric pressure so it is difficult to remove air from a glass bottle.

7.9 What is a barometer?

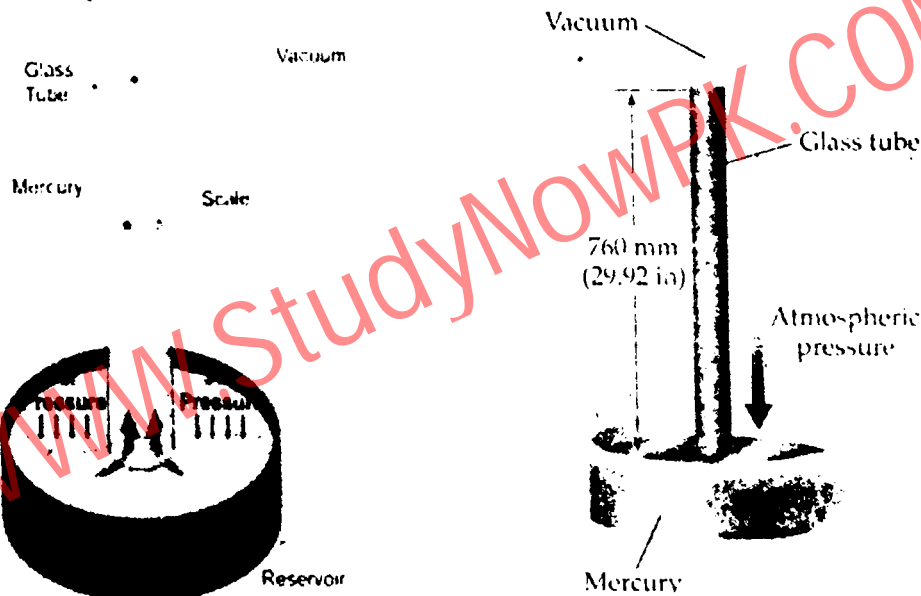
Ans: Measuring Atmospheric Pressure:

At sea level, the atmospheric pressure is about 101,300 Pa or 101.300 Nm^{-2}.

Barometer:

The instruments that measure atmospheric pressure are called barometers. One of the simple barometers is a mercury barometer. It consists of a glass tube 1 metre long closed at one end.

Construction:

After filling it with mercury, it is inverted in a mercury trough. Mercury in the tube descends and stops at a certain height. The column of mercury held in the tube exerts pressure at its base. At sea level the height of mercury column above the mercury in the trough is found to be about 76 cm. Pressure exerted by 76 cm of mercury column is nearly 101,300 Nm^{-2} equal to atmospheric pressure. It is common to express atmospheric pressure in terms of the height of mercury column. As the atmospheric pressure at a place does not remains constant, hence, the height of mercury column also varies with atmospheric pressure.

7.10 Why water is not suitable to be used in a barometer?

Ans: Mercury is 13.6 times denser than water. Atmospheric pressure can hold vertical column of water about 13.6 times the height of mercury column at a place. Thus, at sea level, vertical height of water column would be 0.76 m × 13.6 = 10.34 m. Thus, a glass tube more than 10 m long is required to make a water barometer. Therefore water is not suitable to be used in a barometer

OR (Second Answer)

Following are the reasons why mercury and not water is used in a barometer:

i. Mercury is relatively denser than water, consequently the length of the column of water would have to be about **34 feet** high to exert pressure equal to that of the atmosphere while the column of mercury need to be only **30 inches** to exert pressure equal to that of the atmosphere.

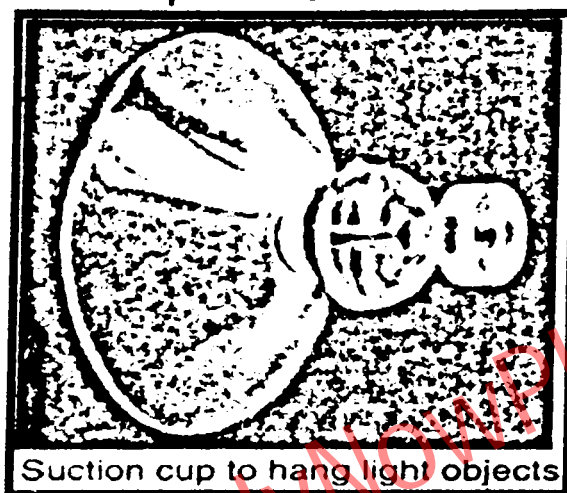
ii. Mercury has a very low vapor pressure when compared to that of water. So it is more sensitive than water to the changes in the atmospheric pressure and rises more quickly to record the changes in the atmospheric pressure.

iii. Mercury's freezing point is much lower than that of water's so it can record the atmospheric pressure at temperatures below that of 0 degrees centigrade.

iv. Mercury does not evaporate easily so very little mercury vapor enters the vacuum above the mercury in the tube.

v. Mercury being a metal shines brightly and so can be used to read the markings on the tube easily.

7.11 What makes a sucker pressed on a smooth wall sticks to it?

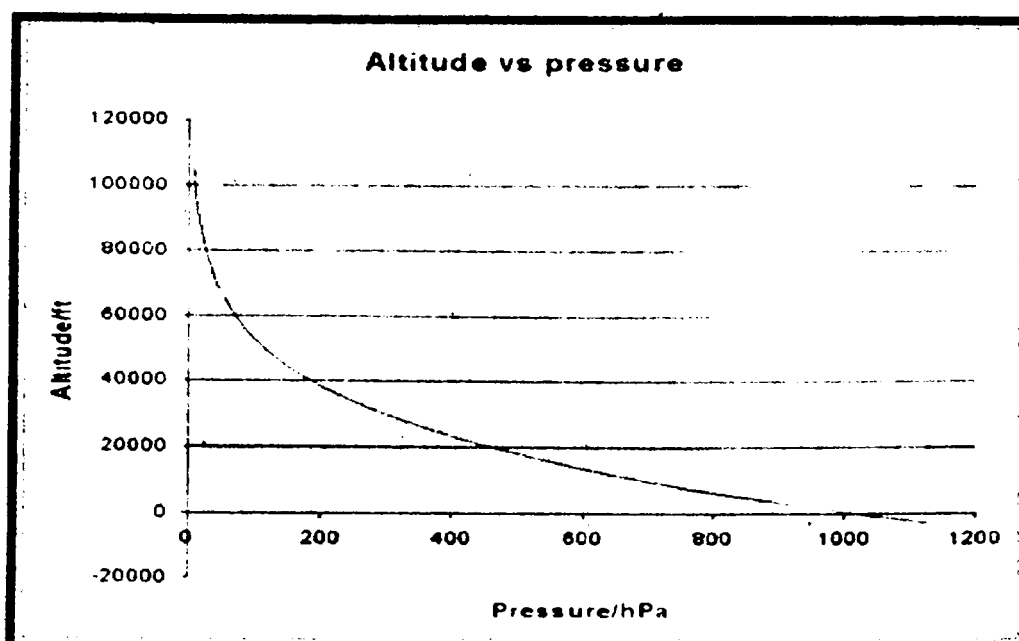
Suction cup to hang light objects

Ans: The sucker is dish shaped, when pressed against a smooth surface the air is forced from beneath the sucker. The rubber makes an air tight seal and the air pressure outside is greater than the air pressure beneath the sucker, thus forcing the rubber sucker to 'stick'.

7.12 Why does the atmospheric pressure vary with height?

Ans: Atmospheric pressure reduces with altitude for two reasons - both related to gravity.

(i) The gravitational attraction (g) between the earth and air molecules is greater for those molecules nearer to earth than those further away - they have more weight - dragging them closer together and increasing the pressure (force per unit area) between them.

(ii) Molecules further away from the earth have less weight (because gravitational attraction is less) but they are also 'standing' on the molecules below them, causing compression. Those lower down have to support more molecules above them and are further compressed (pressurised) in the process.

Note: It is the gravitational force minus the effect of the Earth's spin (an effect that is greatest at the equator).

7.13 What does it mean when the atmospheric pressure at a place fall suddenly?

Ans: The changes in atmospheric pressure at a certain place indicate the expected changes in the weather conditions of that place. For example, a gradual and average drop in atmospheric pressure means a low pressure in a neighbouring locality. Minor but rapid fall in atmospheric pressure indicates a windy and showery condition in the nearby region. A decrease in atmospheric pressure is accompanied by breeze and rain. Whereas a sudden fall in atmospheric pressure often followed by a storm, rain and typhoon to occur in few hours time.

7.14 What changes are expected in weather if the barometer reading shows a sudden increase?

Ans: On the other hand, an increasing atmospheric pressure with a decline later on predicts an intense weather conditions. A gradual large increase in the atmospheric pressure indicates a long spell of pleasant weather. A rapid increase in atmospheric pressure means that it will soon be followed by a decrease in the atmospheric pressure indicating poor weather ahead.

7.15 State Pascal's law.

Ans: Pascal's law:

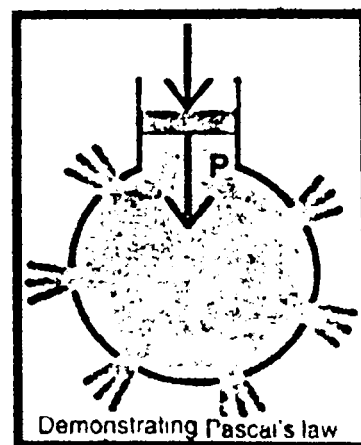
Pressure applied at any point of a liquid enclosed in a container, is transmitted without loss to all other parts of the liquid.

Experiment:

It can be demonstrated with the help of a glass vessel having holes all over its surface.

Fill it with water. Push the piston. The water rushes out of the holes in the vessel with the same pressure. The force applied on the piston exerts pressure on water. This pressure is transmitted equally throughout the liquid in all directions.

Demonstrating Pascal's law

In general, this law holds good for fluids both for liquids as well as gases.

Applications of pascal's law:

Pascal's law finds numerous applications in our daily life such as automobiles, hydraulic brake system, hydraulic jack, hydraulic press and other hydraulic machine.

7.16 Explain the working of hydraulic press.

Ans: Hydraulic Press:

Hydraulic press is a machine which works on Pascal's law. It consists of two cylinders of different cross-sectional areas. They are fitted with pistons of cross-sectional areas a and *A*.

The object to be compressed is placed over the piston of large cross-sectional area *A*. The force F_1 is applied on the piston of small cross-sectional area a. The pressure *P* produced by small piston is transmitted equally to the large piston and a force F_2 acts on A which is much larger than F_1.

Pressure on piston of small area a is given by

$$P = \frac{F_1}{a}$$

Apply Pascal's law, the pressure on large piston of area A will be the same as on small piston.

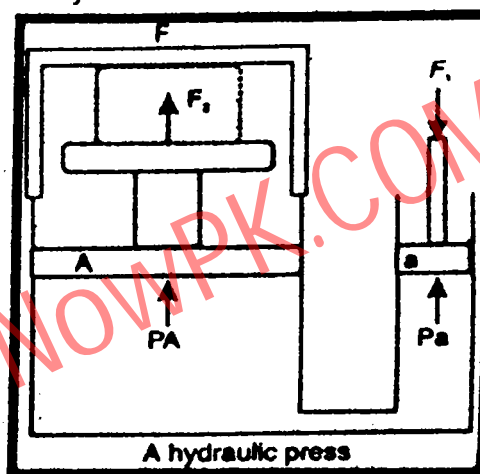
$$\therefore \quad P = \frac{F_2}{A}$$

Comparing the above equations, we get

$$\frac{F_2}{A} = \frac{F_1}{a}$$

$$F_2 = A \times \frac{F_1}{a}$$

or $$F_2 = F_1 \times \frac{A}{a} \quad \text{.............. (i)}$$

A hydraulic press

Note:

Since the ratio $\frac{A}{a}$ is greater than 1, hence the force F_2 that acts on the larger piston is greater than the force F_1 acting on the smaller piston. Hydraulic systems working in this way are known as force multipliers.

7.17 What is meant by elasticity?

Ans: Elasticity:

The property of a body to restore its original size and shape as the deforming force ceases to act is called elasticity.

Due to elasticity we can determine the strength of a material and the deformation produce under the action of a force.

7.18 State Archimedes principle.

Ans: Archimedes principle:

When an object is totally or partially immersed in a liquid, an upthrust acts on it equal to the weight of the liquid it displaces.

Explanation:

Consider a solid cylinder of cross-sectional area *A* and height *h* immersed in a liquid.

Let h_1 and h_2 be the depths of the top and bottom faces of the cylinder respectively from the surface of the liquid.

Then $h_2 - h_1 = h$

If P_1 and P_2 are the liquid pressures at depths h_1 and h_2 respectively and ρ is its density, then according to equation

$$P_1 = \rho g h_1$$
$$P_2 = \rho g h_2$$

Let the force F_1 is exerted at the cylinder top by the liquid due to pressure P_1 and the force F_2 is exerted at the bottom of the cylinder by the liquid due to P_2.

$$\therefore \quad F_1 = P_1 A = \rho g h_1 A$$
$$\text{and} \quad F_2 = P_2 A = \rho g h_2 A$$

Upthrust on a body immersed in a liquid is equal to the weight of the liquid displaced.

F_1 and F_2 are acting on the opposite faces of the cylinder. Therefore, the net force F will be $F_2 - F_1$ in the direction of F_2. This net force F on the cylinder is called the upthrust of the liquid.

$$\therefore \quad F_2 - F_1 = \rho g h_2 A - \rho g h_1 A$$
$$= \rho g A (h_2 - h_1)$$

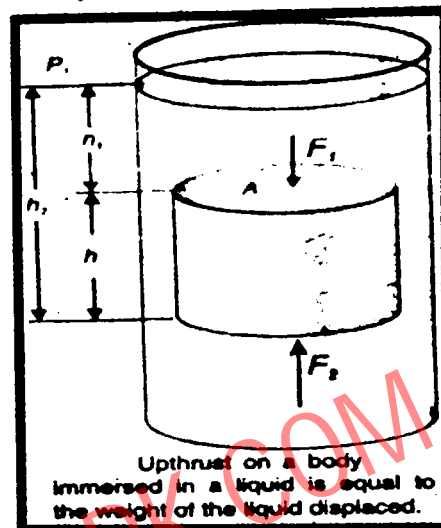
or Upthrust of liquid $= \rho g (Ah)$

$(\because Ah = V)$

or $= \rho g V$

or $= (\rho V)g \quad (\because \rho V = m)$

$= mg$ .... (i)

Here Ah is the volume V of the cylinder and is equal to the volume of the liquid displaced by the cylinder. Therefore, ρgV is the weight of the liquid displaced. Equation (i) shows that an upthurst acts on the body immersed in a liquid and is equal to the weight of liquid displaced, which is Archimedes principle.

7.19 What is upthrust? Explain the principle of floatation.

Ans: Upthrust:

Upthrust is the force that pushes an object up and makes it seem to lose weight in a fluid. (Remember, a fluid means a liquid or a gas).

The upthrust, or buoyancy, keeps ships afloat. The upthrust, or buoyancy, keeps swimmers on top of the water.

Principle of floatation:

An object sinks if its weight is greater than the upthrust acting on it. An object floats if its weight is equal or less than the upthrust. When an object floats in a fluid, the upthrust acting on it is equal to the weight of the object.

In case of floating object, the object may be partially immersed. The upthrust is always equal to the weight of the fluid displaced by the object. This is the principle of floatation It states that:

A floating object displaces a fluid having weight equal to the weight of the object.

Archimedes principle is applicable on liquids as well as gases.

7.20 Explain how a submarine moves up the water surface and down into water.

Ans: Ships and submarines:

A Submarine can travel over as well as under water. It also works on the principle of floatation. It floats over water when the weight of water equal to its volume is greater than its weight. Under this condition, it is similar to a ship and remains partially above water level. It has a system of tanks which can be filled with

and emptied from seawater. When these tanks are filled with seawater, the weight of the submarine increases. As soon as its weight becomes greater than the upthrust, it dives into water and remains under water. To come up on the surface, the tanks are emptied from seawater.

7.21 Why does a piece of stone sink in water but a ship with a huge weight floats?

Ans: It is due to Archimedes principle. Density of ship is less it displace more liquid, experience more upward thrust and floats where as density of stone is more, it displace less liquid experience less upward thrust and sinks

7.22 What is Hooke's law? What is meant by elastic limit?

Ans: Hooke's law:

The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body.

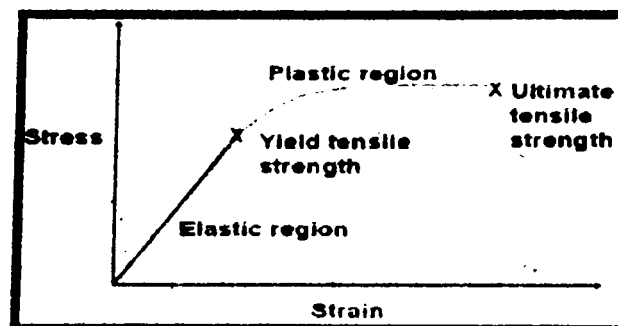
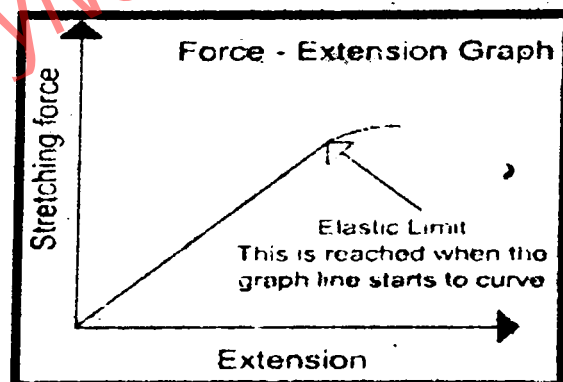
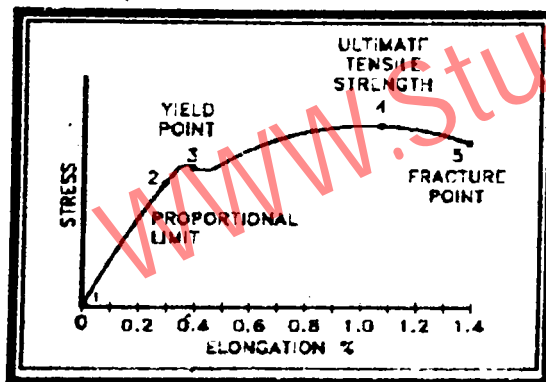
Thus $\quad \text{stress} \propto \text{strain}$

or $\quad \text{stress} = \text{constant} \times \text{strain}$

or $\quad \dfrac{\text{stress}}{\text{strain}} = \text{constant}$

Elastic limit:

The greatest stress that can be applied to a material without causing permanent deformation is called elastic limit.

The stress point at which a material, if subjected to higher stress, will no longer return to its original shape. Brittle materials tend to break at or shortly past their elastic limit, while ductile materials deform at stress levels beyond their elastic limit.

7.23 Take a rubber band. Construct a balance of your own using a rubber band. Check its accuracy by weighing various objects

Ans: We know that the length of a rubber band increases on stretching it. ... of a spring balance is lowered when a body is suspended from

it. It is because the length of the spring inside the balance increases depending upon the weight of the suspended body.
A rubber band scale will be fairly accurate, but only for a short time. Eventually the rubber band will begin to stretch and wear out. A better scale may be made by substituting a metal spring for the rubber band. Such a scale will be just as accurate, and because the spring is made of metal, it will last much longer.

PROBLEMS

7.1 A wooden block measuring 40 cm × 10 cm × 5 cm has a mass 850g. Find the density of wood? (425 kgm^{-3})

Solution: Volume of wooden block = V = 40cm × 10cm × 5cm = 2000 cm^3

$= 2000 \times \frac{1}{100} \times \frac{1}{100} \times \frac{1}{100} m^3$

$= 0.002 m^3$

Mass = m = 850g = $\frac{850}{1000}$ kg = 0.85 kg

Density of wood = ρ = ?

Density = $\frac{Mass}{Volume} = \frac{0.85\ kg}{0.002\ m^3}$ = 425 kgm^{-3}

7.2 How much would be the volume of ice formed by freezing 1 litre of water? (1.09 litre)

Solution: Voume of water = 1 litre

Volume of ice = ?

1 litre of water = 1 kg mass and density = 1000 kgm^{-3}

Since density of ice is 0.92 times of the liquid water therefore,

Density of ice = 1000 × 0.92 = 920 kgm^{-3}

$$Volume\ of\ ice = \frac{mass}{Density}$$

$$Volume\ of\ ice = \frac{1000}{920}$$

$$Volume\ of\ ice = 1.09\ litre$$

7.3 Calculate the volume of the following objects:

(i) An iron sphere of mass 5 kg, the density of iron is 8200 kgm^{-3}. ($6.1 \times 10^{-4} m^3$)

(ii) 200 g of lead shot having density 11300 kgm^{-3} ($1.77 \times 10^{-5} m^3$)

(iii) A gold bar of mass 0.2 kg. The density of gold is 19300 kgm^{-3}. ($1.04 \times 10^{-5} m^3$)

Solution: Mass of iron sphere = m = 5 kg

Density of iron = ρ = 8200 kgm^{-3}

Volume of iron sphere = V = ?

Volume = $\frac{Mass}{Density}$

Volume = $\frac{5}{8200}$

= 0.00060975 = 6.0975×10^{-4}

Volume = $6.1 \times 10^{-4} m^3$

(ii) Mass of lead shot = m = 200 g = $\frac{200}{1000}$ kg = 0.2kg

Density of lead = ρ = 11300 kgm^{-3}

Volume of lead shot V = ?

$$\text{Volume} = \frac{Mass}{Density}$$

$$V = \frac{0.2}{11300} = 0.000017699$$

$$V = 1.7699 \times 10^{-5}\ m^3 = 1.77 \times 10^{-5}\ m^3$$

(iii) Mass of gold bar = m = 0.2 kg

Density of gold = ρ = 19300 kgm^{-3}

Volume of gold bar = V = ?

$$\text{Volume} = \frac{Mass}{Density}$$

$$V = \frac{0.2}{19300} = 0.000010362 = 1.0362 \times 10^{-5}$$

$$V = 1.04 \times 10^{-5}\ m^3$$

7.4 The density of air is 1.3 kgm^{-3}. Find the mass of air in a room measuring 8 m × 5 m ×4 m. **(208 kg)**

Solution: Density of air = ρ = 1.3 kgm^{-3}

Volume of room = V = 8 m × 5 m × 4 m = 160 m^3

Mass of air = m = ?

Mass of air = Density of air × volume of room

Mass of air = 1.3 × 160

Mass of air = 208 kg

7.5 A student presses her palm by her thumb with a force of 75 N. How much would be the pressure under her thumb having contact area 1.5 cm^2? **($5 \times 10^5\ Nm^{-2}$)**

Solution: Force = F = 75 N

Contact Area A = 1.5 cm^2 = $1.5 \times \frac{1}{100} \times \frac{1}{100}\ m^2 = 1.5 \times 10^{-4}\ m^2$

Pressure under the thumb = P = ?

$$P = \frac{F}{A}$$

$$P = \frac{75}{1.5 \times 10^{-4}} = \frac{75}{1.5} \times 10^4 = 5 \times 10^5\ Nm^{-2}$$

7.6 The head of a pin is a square of side 10 mm. Find the pressure on it due to a force of 20 N. **($2 \times 10^5\ Nm^{-2}$)**

Solution: Area of head of a pin A = 10mm × 10mm = $\frac{10}{10}$ cm × $\frac{10}{10}$ cm

= 1cm × 1cm

= $\frac{1}{100}$ m × $\frac{1}{100}$ m

= $10^{-4}\ m^2$

Force = F = 20N

Pressure = P = ?

$$P = \frac{F}{A}$$

$$P = \frac{20}{1 \times 10^{-4}} = 2 \times 10^5\ Nm^{-2}$$

7.7 A uniform rectangular block of wood 20 cm × 7.5 cm × 7.5 cm and of mass 1000 g stands on a horizontal surface with its longest edge vertical. Find
(i) the pressure exerted by the block on the surface
(ii) density of the wood. (1778 Nm^{-2}, 889 kgm^{-3})

Solution: Length of the smallest side of the block = 7.5 cm
Mass of the block m = 1000 g = 1kg
(i) Pressure exerted by the block P = ?
(ii) Density of wood ρ = ?

Calculations: (i) Since the smallest edge of the block is rested on the horizontal surface, therefore, area of the block will be:

$$\text{Area} = A = 7.5\text{ cm} \times 7.5\text{ cm} = 56.25\text{ cm}^2$$
$$= 56.25 \times \frac{1}{100}\text{ m} \times \frac{1}{100}\text{ m}$$
$$= 56.25 \times 10^{-4}\text{ m}^2$$
$$P = \frac{F}{A} = \frac{mg}{A}$$
$$P = \frac{1 \times 10}{56.25 \times 10^{-4}} = 0.1778 \times 10^4 = 1778\text{Nm}^{-2}$$

(ii)

$$\text{Volume} = 20\text{ cm} \times 7.5\text{ cm} \times 7.5\text{ cm}$$
$$= 1125\text{ cm}^3$$
$$= 1125 \times \frac{1}{100}\text{ m} \times \frac{1}{100}\text{ m} \times \frac{1}{100}\text{ m}$$
$$= 1125 \times 10^{-6}\text{ m}^3$$
or $V = 1.125 \times 10^{-3}\text{ m}^3$
$$\text{Density} = \frac{Mass}{Volume}$$
$$\text{Density} = \frac{1}{1.125 \times 10^{-3}} = 0.8888 \times 10^3\text{ kgm}^{-3} = 888.8\text{ kgm}^{-3}$$
$$\text{Density} = 889\text{ kgm}^{-3}$$

7.8 A cube of glass of 5 cm side and mass 306 g, has a cavity inside it. If the density of glass is 2.55 gcm^{-3}. Find the volume of the cavity. (5 cm^3)

Solution: Side of the cube = 7.5cm
Mass of the cube = m = 306g
Density of glass = ρ = 2.55gcm^{-3}
Volume of the cavity = V = ?

Volume of the whole cube = 5 cm × 5 cm × 5 cm = 125 cm^3
$$\text{Volume of the glass} = \frac{Mass}{Density}$$
$$= \frac{306}{2.55} = 120\text{ cm}^3$$
Volume of the cavity = 125 cm^3 – 120 cm^3 = 5cm^3

7.9 An object has weight 18 N in air. Its weight is found to be 11.4 N when immersed in water. Calculate its density. Can you guess the material of the object? (2727 kgm^{-3}, Aluminum)

Solution:
Weight of object in air = w_1 = 18N
Weight of object immersed in water = w_2 = 11.4N

Density of water = ρ = 1000 kgm^{-3}

(i) Density of the object = D = ?

(ii) Nature of the material = ?

(i)

$$D = \frac{w_1}{w_1 - w_2} \times \rho$$

$$D = \frac{18}{18 - 11.4} \times 1000$$

$$= \frac{18}{6.6} \times 1000 = 2.727 \times 10^3 = 2727\ kgm^{-3}$$

(ii) The density of aluminum is 2700kgm^{-3}, the above calculated value of density is 2727 kgm^{-3} nearest to the density of aluminum it, so the material of the object is aluminum.

7.10 A solid block of wood of density 0.6 gcm^{-3} weighs 3.06 N in air. Determine (a) volume of the block (b) the volume of the block immersed when placed freely in a liquid of density 0.9 gcm^{-3}?

(510 cm^3, 340 cm^3)

Solution: Density of wood = D = 0.6 gcm^{-3}

Weight of wooden block = w = 3.06N

Since w = mg or $m = \frac{w}{g} = \frac{3.06}{10} = 0.306kg = 306g$

Density of liquid D = 0.9 gcm^{-3}

(i) Volume of the block V = ?

(ii) Volume of the block immersed in a liquid V = ?

$$\text{Density} = \frac{Mass}{Volume}$$

or

$$\text{Volume} = \frac{Mass}{Density}$$

$$V = \frac{306g}{0.6gcm^{-3}} = 510\ cm^3$$

(b)

$$\text{Volume} = \frac{Mass}{Density}$$

$$V = \frac{306\ g}{0.9\ gcm^{-3}}$$

$$V = 340\ cm^3$$

7.11 The diameter of the piston of a hydraulic press is 30 cm. How much force is required to lift a car weighing 20000 N on its piston if the diameter of the piston of the pump is 3 cm? (200 N)

Solution:

Diameter of the piston = D = 30 cm

Radius of the piston = $R = \frac{D}{2} = \frac{30cm}{2} = 15\ cm = \frac{15}{100} m = 0.15\ m$

Area of the piston = A = $2\pi R^2 = 2 \times 3.14 \times (0.15)^2$

$A = 0.1413m^2$

Weight of the car $w = F_2 = 20000N$

Diameter of the piston d = 3cm

Radius of the piston $r = \frac{d}{2} = \frac{3}{2} = 1.5\ cm = \frac{15}{1000} m = 0.015m$

Area of the piston $a = 2\pi r^2$

$a = 2 \times 3.14 \times (0.015m)^2$

$a = 1.1413 \times 10^{-3}\ m^2$

Force = F_1 = ?

$$\frac{F_1}{a} = \frac{F_2}{A}$$

$$F_1 = F_2 \times \frac{a}{A}$$

$$F_1 = 20000N \times \frac{1.413 \times 10^{-3}}{0.1413}$$

$$= 20000N \times 0.01$$

$$F_1 = 200\ N$$

7.12 A steel wire of cross-sectional area $2 \times 10^{-5}\ m^2$ is stretched through 2 mm by a force of 4000 N. Find the Young's modulus of the wire. The length of the wire is 2 m. **($2 \times 10^{11}\ Nm^{-2}$)**

Solution: Cross-sectional area = A = $2 \times 10^{-5}\ m^2$

Extension = ΔL = 2 mm = $2 \times \frac{1}{1000}$ m = 0.002 m

Force = F = 4000N

Length of the wire = L = 1m

Young's modulus = Y = ?

$$Y = \frac{FL}{A\Delta L}$$

$$Y = \frac{4000 \times 2}{2 \times 10^{-5} \times 0.002} = \frac{8000}{0.004 \times 10^{-5}}$$

$$Y = \frac{8000}{0.004} \times 10^{-5}$$

$$Y = 2{,}000{,}000 \times 10^{-5} = 2 \times 10^{11}\ Nm^{-2}$$